Astronomy 102 — Recitation #6

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Review of lectures 11–12 and Ch. 4–5.

Degeneracy pressure

- When elementary particles (electrons, neutrons, etc.) are confined to extremely small volumes, they behave as waves and exert a pressure on their confining "box."
- This degeneracy pressure can be strong enough to balance the force of gravity, stopping the collapse of a star.

White dwarf stars

- White dwarf stars are stars that are supported by electron degeneracy pressure.
- They have the mass of a typical star ($\leq 1.4 M_\odot$), but they are only as big as a planet; their densities are extremely high!
- The greater their mass, the smaller the size of the white dwarf. This is a result of the electron degeneracy pressure: if you pack on more mass, the electrons are shoved closer together in order to increase their degeneracy pressure and push back against gravity.
- White dwarfs are very faint, cool objects. If left alone, they will slowly cool and remain stable for eternity.

Relativistic mass

When a massive body moves close to the speed of light, its mass appears to increase according to

$$m = \frac{m_0}{\sqrt{1 - \left(\frac{V}{c}\right)^2}} = \gamma m_0 \tag{1}$$

m_0 is the body's rest mass (the mass measured in the rest frame of the body).

Supernovae

Classic nova Explosion of accreted material (mainly hydrogen) off the surface of a white dwarf; caused by initiation of hydrogen fusion on surface of white dwarf; white dwarf survives.

Type Ia supernova Explosion of both accreted material and white dwarf; caused by initiation of carbon fusion inside the white dwarf, when the total mass of the white dwarf reaches $1.4 M_\odot$; white dwarf is destroyed.

Type II supernova Explosion of outer material around a stellar core that was more massive than $1.4 M_\odot$; caused by the stellar core collapsing beyond the electron degeneracy pressure limit, causing electrons and protons to combine to form neutrons and further collapsing until neutron degeneracy pressure supports the core from further collapse; remnant is a neutron star (mass no larger than $2.2 M_\odot$).

In-class problems

1. *Particle confinement*

   (a) Describe how electrons and neutrons exert a pressure when they are confined to a small volume.

   (b) Photons also exhibit both particle and wave-like properties. Why do photons not also create a photon-degenerate gas?

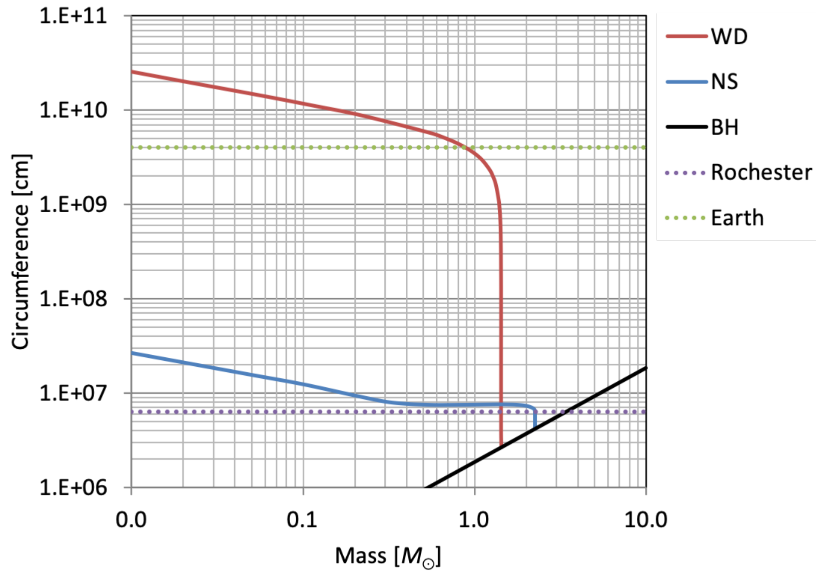
2. Are higher mass white dwarfs larger or smaller than lower mass white dwarf stars? Why?

3. What is the mass of an electron ($m_e = 9.109 \times 10^{-31}$ kg) moving at $0.75c$? A proton ($m_p = 1.673 \times 10^{-27}$ kg)?

4. What is the speed of an object that appears to have a mass ten times larger than its rest mass?

5. What are the main differences between a white dwarf and a neutron star?

6. Answer the following questions using the graph shown below.



   (a) What is the circumference of a white dwarf with a mass of $0.3M_\odot$?

   (b) What is the circumference of a neutron star with a mass of $0.02M_\odot$?

   (c) What is the circumference of a black hole with a mass of $0.7M_\odot$?

7. Can an isolated white dwarf explode in a classic nova? Why or why not?

8. What are the differences between a Type Ia and Type II supernova?